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AUTHOR Stonebarger, Bill
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ABSTRACT

This booklet considers scientific methods and values from three aspects; time, space, and spirit. Time refers to a sense of history; space refers to geography; and spirit refers to life and thought. Several chapters on the history and values of science, a time line related to the concepts, a map of the important geography related to these concepts, a glossary of important terms, and a list of several study suggestions are included. (CW)

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Scientific Methods and Values

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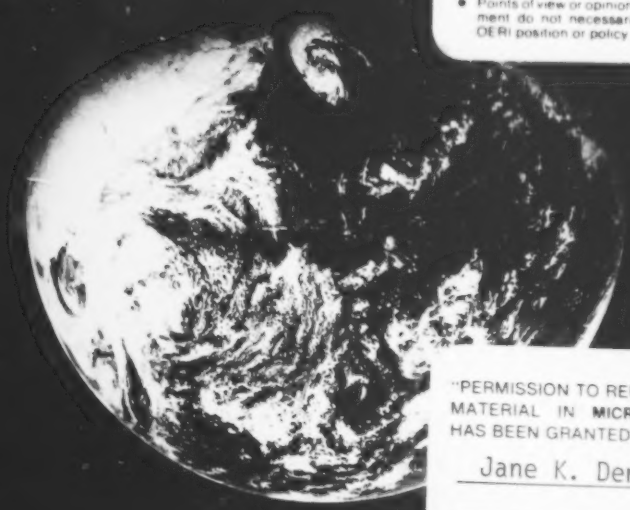

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A HAWKHILL LEARNING POWER BOOK

2

TIME, SPACE AND SPIRIT

KEYS TO SCIENTIFIC LITERACY

To the student,

This short book will help you understand our modern world. It has changed a lot since your parents were born. Even more since you were born. And it will change still more–much more–in your lifetime.

What is behind most of these big changes? Two things. Science and technology.

What can you do about it? The first step is to understand more about science and technology and how they connect with our world. Especially the ever-growing world of free democratic societies. One way to do this–the way this book follows–is to look at the world from three angles: *Time, Space* and *Spirit*.

Time means history. You can learn how science and technology have worked in the past and are working today.

Space means geography. You can learn where important things happened in the past and are happening today.

Spirit means life. The life of the mind. You can learn the key words, concepts and ideas that power science and technology (and society) today.

This book teaches about science, technology and society from all three of these angles–*Time, Space* and *Spirit*.

Read on.

This book belongs to:

Scientific Methods and Values

Bill Stonebarger
Illustrations by Lin Haley

Hawkhill Associates
Madison, Wisconsin

This book is one of a series of sixteen Learning Power Books in the *Time, Space and Spirit–Keys to Scientific Literacy* series. It is designed to accompany the video program of the same name.

The *Time, Space and Spirit–Keys to Scientific Literacy* series was written and produced with consultation from the History of Science Department at the University of Wisconsin-Madison.

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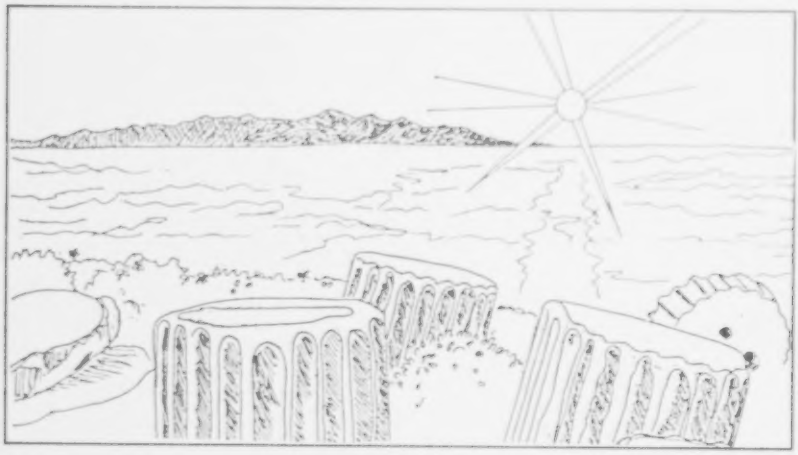
Part 1: The Growth of Science



"wonders are many"

"Wonders are many, and none is more wonderful than man. The power that crosses the white sea, making a path under surges that threaten to engulf him."

That's how Sophocles, a poet who lived in ancient Greece some 2500 years ago, described the human adventure.

Sophocles could have been giving a definition of science, as accurate then as it is now.

science as wonder and power

The two key ideas of science are here—wonder and power. Let's see how these two key ideas have grown and changed from their birth in ancient Greece to their flowering all over the world today.

the power side

The power side of science is the same power that learned how to cross the white sea; how to grow crops instead of gather them; how to herd animals

instead of hunt them; how to make wheels, mold pots, extract metals and read and write languages. This power side of science came into the world long before the ancient Greeks.

early civilizations

It was created on this planet by people of all races, all over the ancient world. It was most powerfully developed in the rich river valleys of China, India, Africa and South America. It was created and nurtured by unknown geniuses who passed on their powerful knowledge to their children and their children's children.

origins of technology

Today we call this power *technology*. Today every mechanic, engineer, inventor, craftsperson and scientist stands on the shoulders of these early human pioneers.

the wonder side

There is another side to modern science. The wonder side. The same wonder you hear in the small child's questions.
"Why is the sky blue?"
"What are stars made of?"
"How did the world begin?"
"Where did I come from?"

People from very ancient times also asked these questions. Some of the first people who both asked them, and then dared to answer them in a scientific way lived in ancient Ionian Greece some 2500 years ago.

Thales

The man generally considered to be the world's first natural philosopher/scientist was a Greek named Thales. The question that most fascinated Thales was "What is the world made of?"

"all is water"

His answer, water. The world, as he pictured it, was like a large island that floated in a cosmic sea of water. The water forms itself into soil and into plants and animals, and then all these dissolve themselves back into the cosmic ocean in eternal comings and goings.

Miletus

Today what used to be the Ionian Greek city of Miletus, where Thales lived, is just a ruin of stones in western Turkey, on the shores of the Mediterranean Sea. But 2500 years ago, Miletus was the center of an exciting new idea in the world, the idea we today call science.

answers in natural terms

Thales, and the other natural philosophers of Greece, not only asked big questions like "what is the world made of?" but they answered these questions in natural terms. That is, they left out the gods. The world, said Democritus, has no beginning, nor will it have an end. The world is made of atoms in the void.

evolution

Human beings, like other living creatures, evolved on this earth from simpler creatures in the water, said Anaximander.

natural causes for disease

Diseases have natural causes, and therefore must have natural cures, claimed Hippocrates.

few experiments

Most of the answers given by the Ionian Greeks were pure speculation. They did few, if any, experiments. They had the wonder, in other words, but not yet the power. But this new confidence in natural reason laid important stones in the foundation of the sciences to come. A foundation upon which laterhumans like Galileo, Newton, Darwin, Curie, Einstein and Bohr would build the edifice of modern science.

rational thought grows

After the Ionians, later Greek, Egyptian and Roman thinkers like Plato, Aristotle, Archimedes, Ptolemy and Galen added to, and multiplied, the range and power of rational thought. But for the next giant step forward, the human race had to wait almost two thousand years. This step came during what is known as the Renaissance.

Arab science

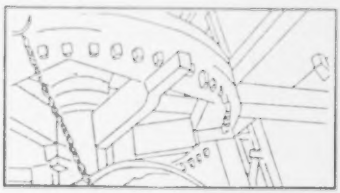
Western civilization itself went into decline after the fall of the Roman Empire. For many hundreds of years it was the Arab and Moslem world that preserved and added to the beginnings made in Greece.

Middle Ages

When we think of the Middle Ages today, we think of lords and ladies, of castles and cathedrals, of knights and monks. Scholars in the history of science point out that the Middle Ages was also of a time of much progress in science.

new technology

It was during the Middle Ages, for instance, that humans learned new ways to harness the power of nature for human purposes. New technologies were invented that used the power of the wind and water to grind corn, pump water and saw wood. Harnesses for horses



were invented that more effectively used animal power. Then came new ways to improve agriculture, navigation and then in a rush, the printing press, compass and telescope as the Middle Ages merged into the Renaissance.

new visions

During the Medieval days, too, the wonder side of science was slowly gaining vision. The ancient books of Greek scientists like Aristotle, Archimedes and Ptolemy were rediscovered, translated and added to. A new interest was slowly growing in reason, in the ability of human beings to decipher the mysteries of nature, as well as the mysteries of God.

modern science in the Cathedral at Pisa

Here in the great Cathedral in Pisa, Italy, a young university professor used to sit and watch an altar lamp swing slowly back and forth. Back and forth. Curious, he timed its swing with the only watch available then, his own pulse. He found it always seemed to take the same amount of time for one swing–no matter how wide or narrow the swing. He had discovered the principle of the pendulum clock. More important, Galileo Galilei had taken a first step toward uniting power and wonder, launching modern science on its incredible voyage of discovery.

a new way of looking at motion

In the course of a long and adventure-filled life, Galileo helped to lay the scientific and mathematical foundations for a new way of looking at motion. A way that not only explained how things fall to the ground, but also how the moon revolves around the earth and how the earth and all the other planets move in orbits around the sun.

Galileo not alone

Galileo didn't do this alone, of course. Other giants of his day, men like Copernicus, Kepler and Tycho Brahe played important parts in creating modern science. Probably the most important single man of all was born the same year Galileo died. He was born and lived in England. His name was Isaac Newton.

Newton

A famous English poet of the day, Alexander Pope, expressed the general opinion of the time about Newton's achievements.

"Nature and Nature's laws lay hid in night:
God said, Let Newton be!
and all was light."

thinkers and doers together

During these heady days, for the first time in human history, the heavy thinkers and the heavy doers were edging closer together. It was no longer good enough to just ask big questions and give purely speculative answers. The answers had to have practical consequences, consequences you could see, feel, touch, taste and measure.

surprise

When you did thus test your theories in practice, you often were surprised. Thinking about the surprise, you could go back and change your answers, making them more truly fitting with reality. The idea we call experimental science was beginning to take shape.

progress in wonder and power

In the next few centuries, progress in understanding and in controlling natural events with the aid of experimental science began to gain momentum. Sometimes the wonder side of science led the way, especially in astronomy and natural history. And sometimes the power or technology side of science led the way, as in the fast pace of invention in the nineteenth century.

the power side leads to the Industrial Revolution

The nineteenth century in Europe and North America was the century of the Industrial Revolution. The Industrial Revolution combined the power of science and technology with the equally powerful ideas of democracy, capitalism and free trade. Out of this creative mix came inventions like the steam engine, electrical generators and motors, wireless communication, internal combustion engines, as well as a host of new scientific tools.

progress in life sciences

Though it came later, progress was also made in the life sciences and in medicine. Instead of basing cures to human ills on folk medicine, astrology or other fanciful theories, humans slowly began to rely more on the scientific discoveries of biologists, chemists and physicians. Why? Because they worked better.

control of epidemic disease

In the late nineteenth century and then most dramatically in our own twentieth century, most of the terrible epidemic diseases were conquered. Some have called this the "noblest chapter in human history." And with good reason. Diphtheria, typhoid, smallpox, cholera, syphilis, tuberculosis, polio and plague all gave way before the onslaught of power and wonder people. And that conquest continues today in countries around the world.

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social sciences

In our time, the influence of scientific method and of scientific values has spread into the social and political worlds as well. As yet, it has not proved as useful there as in the physical and life sciences, but few would doubt the potential for the future.

stereotypes of scientists

In such a fast survey of the growth of scientific methods and values, there is a danger we think of famous scientists as being godlike. Or imagine they all use a magical tool called scientific method, and through its use, perform miracles. Some people think of scientists as men and women in white coats, hunched over their test tubes and machines, working all hours of the night, risking their own and other people's lives in an almost demonic desire to know.

scientists as individuals

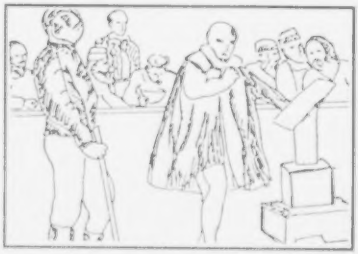
When you read of the lives of individual scientists, you quickly see it wasn't that way. You see, instead, how scientists in their personal lives have been just about as varied a group an any other that has lived on this planet.

John Dalton

John Dalton, for instance, was a retiring modest bachelor. Poor, colorblind, he taught in a small Quaker elementary school in England. He never married. "I just never had time," he claimed. He was rather clumsy in the science laboratory. Yet despite these traits, or perhaps because of them, he managed to invent a theory of atoms that brought a revolution to the new world of science.

Galileo

Galileo, on the other hand, was as aggressive and social as Dalton was retiring and solitary. Galileo never married either, but he lived with a mistress for many years. He loved wine. He loved a good argument. In fact, he was continually getting into hot water with the authorities not only because of his unorthodox opinions, but also because he was so abrasive in putting them forward. And yet despite these traits, or perhaps because of them, he managed to overturn centuries of error and to father modern physics and astronomy (as well as five children with his unwed mistress). And throughout it all, to remain a devout Catholic.



If we had world enough and time, it would be easy to multiply these two examples a hundred-fold. A thousandfold.

Charles Babbage and Ada Lovelace

There were grumpy geniuses like Charles Babbage, who designed the world's first true computer. And charming young geniuses like Ada Lovelace, who helped him design it and went on to herself become the world's first computer programmer. As well as to lose most of her money trying to use the computer to pick the winners of horse races!

Henry Cavendish

There have been wealthy, irascible woman haters like Henry Cavendish who discovered hydrogen, the composition of water and weighed the earth.

Charles Darwin

There have been devoted family men like Charles Darwin who shocked and changed the world with a theory of evolution by natural selection.

the Curies

There have been poor young women like Marie Curie, who discovered radium, pioneered the way for women in science, and was the first person ever to win two Nobel prizes. In between all these scientific achievements, she also managed to have a happy marriage and two daughters who became famous in their own right as writers and scientists.

no typical scientist

There have been, and are, devoutly religious scientists. There have been, and are, devout agnostic and atheist scientists. Family men and women, gay men and women, black men and women, young and old men and women.

Handicapped and not, social and not, athletic and not, clever in the laboratory, and clumsy with their hands.

In other words, there is no typical scientist, just as there is no typical business person, teacher, artist or truck driver.

scientific methods and values

But there is such a thing as science. And there are such things as scientific methods and scientific values. Methods and values that all the major and minor figures in science, yesterday and today, have followed and lived by.

Part 2: The Methods and Values of Science

the mystery

"The mysterious," said Albert Einstein, "is the source of all true art and science."

the work

"Science," said Thomas Edison, "is one percent inspiration and ninety-nine percent perspiration."

the surprise

"A mouse," said Walt Whitman, "is miracle enough to stagger sextillion of infidels."

Each of these three ingredients–the mystery, the work and the surprise–is indeed a part of modern science. And there are others.

what is scientific method?

When people write or talk about scientific method, they often write or talk as if it were a single thing. Most scientists would disagree.

The truth is, most scientists don't particularly like to talk about their methods at all. They much prefer to tell you about their problems and their results. And usually with heavy use of phrases

like "it seems," "the probability is," "within the limits of our experiments."

not going beyond the evidence

In other words, besides mystery, work and surprise, scientists also prize caution, limits, not going beyond the evidence, taking care that whatever statement is made, it should be verifiable in practice. Wonder, speculation, mystery are fine, so long as they have a firm connection to power, hard data, fact.

the imagined world and the real world

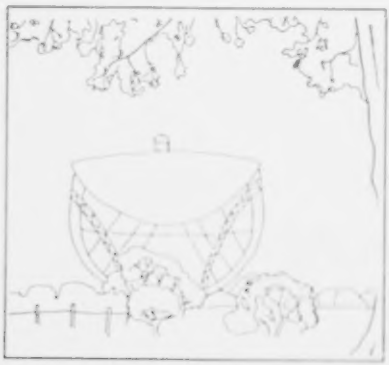
A Nobel laureate, Sir Peter Medawar, put it this way. "Most of the day-to-day business of science consists in trying to find out if your imagined world is anything like the real one. If it is not, we have to think again."

mystery and fact

So there you have it–the two sides–the two tricks to both scientific methods and scientific values. Imagination and reality. Mystery and fact. Wonder and power.

on the one side, fantasy

On the one side, scientific methods and scientific values are on the side of wild fantasy. On the side of the most outrageous, passionate, imaginative search you can imagine. A search for a new world of truth and light. A way of penetrating the mysteries of the cosmos. The mysteries of the human mind and body. The mysteries of an ant hill, a new gear system or a new molecule.



on the other side, caution

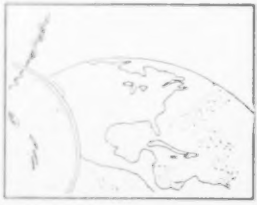
On the other side scientific methods and values are on the side of sober caution. On the side of sticking to the facts. Of care, nitpicking attention to detail, scrupulous concern for absolute honesty.

knowledge that works

Once you get the imagined world and the real world into a working relationship, you have science. You have knowledge. Knowledge that works. Knowledge that can send off some of the brightest sparks of joy and delight humans seem capable of seeing.

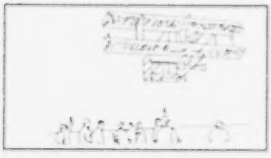
spaceship earth

Many humans who are not professional scientists experienced some of that joy that works when they saw the first blue-white photos of our spaceship earth.

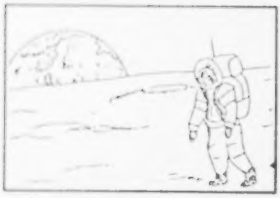


what came before

Think how much imagination and care went into getting those first photographs from space and you will have a better idea of what scientific methods and values are all about. Not only the imagination and care of the engineers, scientists, mechanics and astronauts today, but all the engineers, scientists, mechanics and pioneers whose work came before. The people who first invented cameras, who perfected film. The people who first built and flew airplanes, designed and tested the first rockets. The people who learned to make better steel, plastics, aluminum and ceramics. The people who dreamed up computers and computer programs. The pioneers who had the courage and skill and perseverance to never give up, to try again after a failure, to take still another chance–and to succeed.



"standing on the shoulders of giants"



Each scientific worker has been able, in other words, to build on the work of those who have gone before. Preparing the way. As one of the greatest scientists, Isaac Newton, put it, "If I have seen further than other men, it is because I have been able to stand on the shoulders of giants."

harsh standards

Each scientific worker has been subject to a harsh standard. Does it work? Does it predict correctly? Does your fantasy world fit with your reality world? And not for you alone, or for you and a few like-minded friends–does it work for the public, for everyone in all times and all places? Only so can it be called science. Only so can it be called true.

astrology

Not every enterprise that has claimed the title of science can pass these stern tests. Astrology, for instance, is also an attempt to connect a fantasy world with a reality world. There have even been some famous scientists, like Johannes Kepler, who have been astrologers as well.

does astrology work?

Over the long pull, however, astrology fails the most crucial of all scientific tests. It doesn't work. Publicly. At all times and all places. Mind you, astrology does work sometimes. The imagined world of a personal horoscope sometimes may even may predict with astonishing accuracy a person's traits or a person's future actions. But when faced with a critical, public test,

astrology always flunks. And astrology has flunked over and over again for centuries. One result of this failure is that knowledge of astrology today gives no more power to individuals or to society than knowledge of astrology did a thousand years ago.

knowledge and power

On the other hand, knowledge of astronomy, or physics, or chemistry, or biology, or ecology or geology–gives power a thousandfold as great today as it did a thousand years ago. Or even ten years ago!

occult "sciences"

The same contrasts stand out when you compare genuine science with other occult practices of the past and present. Psychic surgery, astral projection, spoon-bending, miracle cures, Bermuda triangles, etc. All these can point to remarkable instances where the world of fantasy did indeed seem to connect with our world of reality. But none of these occult practices can pass the harsh scientific test of public verification over the long stretch. And as a result, none of them has led to any real increase in human power or wisdom. In other words, not one of them works–not publicly, consistently, reliably.

feeling better, as sight dims

Instead of being able to see farther by standing on the shoulders of those who have gone before, with the occult, at best, you can feel better by holding hands with those who believe as you do. And as the horizon fades, the sight dims.

Let's be more specific now. Granted that science tries to connect an imagined world with the real

world–what hints do we get from successful connections of the past as to just how it can be done most fruitfully today.

There is no recipe.

"10,000 ways that won't work"

Many textbooks claim that scientific method means starting with a problem. You construct a hypothesis to solve the problem. Then you test to see if your hypothesis is true.

Most of the time, the hypothesis turns out to be false. But then, that in itself is knowledge. Verifiable, scientific knowledge. As Thomas Edison once said, "I may not know how to make a light bulb yet, but I do know 10,000 ways that won't work."

more complicated and more interesting

This way of looking at scientific method is true enough, as far as it goes. But it doesn't go nearly far enough. In the real world scientific laboratory, in the real world scientific study, in the real world, it gets more complicated. And more interesting.

to find something new

For one thing, no seed can grow unless you prepare the soil. In order to find out something new you need to know many things old. You are not likely to discover a cure for cancer if you don't know anything about cells, about genetics, about biochemistry, perhaps even about poetry and

anthropology. There is no formula, but experience has shown that the more intensely you become preoccupied with a problem, the more sides you see to the problem, the greater your chances of solving it. With the emphasis on intensity.

concentration

Often what it takes is a near total immersion in the problem, the challenge, the quest. Which is why scientists often are looked on as absent-minded. It is not that their mind is "absent" but rather that it is so intensely concentrated on the challenge that they don't pay attention to anything else at the time.

can you know too much?

Of course experience has also shown–note the scientific caution again–that it is possible to know too much about a subject. To know so much that your mind is not as free to imagine new connections. Connections that may show some of what you know is not true, or is only a dangerous and misleading half-truth. This is one reason some of the best scientific work is often done by quite young men and women. They don't know so much that isn't true.

no magical recipe

Again, there is no magical recipe. Study in, around and about a subject. Study intensely, deeply, widely–but don't believe everything you read! Besides the study of past knowledge in the field, the scientist would usually want to get his or her hands involved. Or at least to think ideas

that someone else could in fact test out with fingers and eyes and noses and ears–and if possible, measurements in numbers.

fooling around

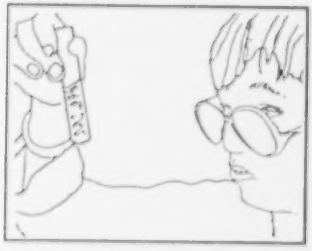
Sometimes, more often than not, it works the other way around, too. The scientist, or technician, or engineer, or craftsperson comes across a new idea in the process of constructing something. Or experimenting with something. Or just plain fooling around with something.

sealing wax and string

One recent historian of science pointed out that the unsung heroes of the famous Cavendish Laboratory at Cambridge University were the technicians who used sealing wax and string to patch together the custom-made research equipment. And in the process helped piece together the pieces of modern atomic theory. All, incidentally, with a yearly budget for research equipment of less than a thousand dollars a year in 1908.

connections between technology and theory

Since there is this intimate connection between wonder and power that runs through all the best of science, it is not surprising that there is such an intimate connection between technology and theory. Between the workshop, the laboratory and the study. Different scientists are more at home in one than another, but all are aware of how important each of the places and pieces is.



scientific values

We have talked of scientific methods. What about scientific values? There is a close connection between methods and values in science. Sometimes it is hard to tell which is which. You

can look at scientific values much as you look at scientific methods.

passion and purity

On the one hand, caution, limits and care. On the other hand, imagination, wonder and passion. The methods of science are there, and so are the values. Both in the passion of the search and in the purity of the limitations. Wonder and power, hope and caution, mystery and fact, paradoxes that work.

Murphy's Laws

On the side of limitation, you might think of scientific values in terms of the famous Murphy's Laws. "If anything can go wrong, it will." In other words science is not satisfied with easy answers that work once but are not reliable over the long pull. Once you really know something, it will work time and time again.

the skeptic

Just because it is in the newspapers doesn't mean it is so. In other words, science is perpetually the skeptic. Show me. Prove it to me. Prove it to me not in words, but in deeds. In experiments.

honesty is the best policy

Honesty is the best policy–but cash on the line is even better. In other words, results count. And the worst sin a scientist can commit is to falsify his or her results. To lie. Science does have an advantage here. The cheater, the liar, and there have been some in science, is almost certain to be found out. Because part of the very core of scientific truth is that it can and must be verified publicly, independently. It is, thus, self-correcting.

"the spirit of liberty"

"The spirit of liberty is the spirit that is not quite sure it is right." This is a "law" made by a famous

judge, Learned Hand. He could have been talking about science as well as of democracy. And, as a matter of fact, science at its core is a profoundly democratic enterprise. The passion of a free people, who have faith, but a faith that can stand challenge. A faith that can change as new knowledge comes along.

Riley's Laws

On the passion side of science, we might coin some new laws. Let's call them Riley's Laws (Murphy's optimistic cousin).

the mysterious

"The mysterious is the source of all true art and science." Albert Einstein said that. He also said "imagination is more important than knowledge."

the man who measured it

"It is not the immensity of space that should command our wonder, but rather the man who measured it."

"dare to be naive"

"Dare to be naive." Advice given by a modern scientist and engineer, Buckminster Fuller.

the scientist and the dancer

"There is a vitality, an energy, a quickening, which is translated through you into action. And because there is only one of you in all time, this expression is unique. And if you block it, it will never exist through any other medium and be lost. The world will not have it." Said by a dancer, Martha Graham, but she could have been talking about one of the most precious values of science as well. The conviction that in the long run, human beings play a part, human beings have a voice and a vote in the universe.

Sophocles put it into words

Which brings us back to the beginning. To that fabled time in ancient Greece, 2500 years ago, when Sophocles put it into words.

"Wonders are many,
and none is more wonderful than man ...
the power that crosses the white sea,
making paths under surges
that threaten to engulf him."

TIME ...

To understand the world of today it helps to know something about the world of yesterday. Kings and queens, wars and famines, presidents and paupers have all played a part. But more important than any of these in changing the past world into the world of today has been science and technology. The time line below will help you place important events and people in historical time.

EVENTS IN WORLD HISTORY		EVENTS IN SCIENCE & TECHNOLOGY
	500 B.C. / 500 B.C.	
600-300 B.C. Golden Age of Greece		600-350 B.C. early Greek philosopher scientists
	A.D. 1 / A.D. 1	
Birth of Christ		
200 B.C. to A.D. 450 Roman Empire		
	500 / 500	
500-1300 The Middle Ages		500-1300 advances in technology, rediscovery of ancient books
	1000 / 1000	
1400-1700 Renaissance		1400-1700 modern science begins with Galileo, Newton and others
1776 Declaration of Independence	1500 / 1500	
1800-today Industrial Revolution		1800-1900 rapid advances in physics, chemistry and biology
		1900-today science & technology accelerate
	2000 / 2000	

EVENTS IN WORLD HISTORY		EVENTS IN SCIENCE & TECHNOLOGY
1776 . American Revolution		
	1800	1790-1810 foundations laid for modern chemistry by Cavendish, Priestley, Lavoisier, John Dalton and others
		1831-36 Darwin's world trip–modern biology begins
		mid-1800s Faraday, Maxwell & others make fundamental discoveries in electricity
	1850	
1861-65 Civil War		
		late 1800s Pasteur, Koch & others conquer infectious diseases
		1880 Edison's first electric light
		1903 Marie Curie wins two Nobel Prizes for work on radiation
	1900	
1914-18 World War I		
1929-38 worldwide economic depression		1930 penicillin discovered
		1941 first working nuclear reactor
1939-45 World War II		
	1950	
1950-52 Korean War		1953 Crick & Watson publish paper on DNA structure
		1957 USSR sends up Sputnik, first artificial satellite
1966-73 Vietnam War		
		1976 Apple brings out first personal computer
	2000	

SPACE ...

There is a saying, "If you don't know where you are going, any road will get you there." One of the important parts of knowing where you are going is a knowledge of geography. The map below will help you to locate the important events and people discussed in this book.

1. Ionian Greece Where the world's first philosopher/scientists lived and worked. What used to be Ionian Greece is now a part of modern Turkey.

Asterisks mark areas of early agricultural civilizations where human technology first developed. In all of these civilizations there was also progress in charting the skies–identifying stars and planets, keeping time and devising a calendar.

1. Pisa, Italy — In the great cathedral here, Galileo Galilei began his famous investigations into motion and gravity. Also demonstrated his theories at the Leaning Tower of Pisa.

2. Newton's home in England — Here in north central England, Newton lived and worked out his revolutionary laws of motion and universal law of gravitation.

3. Paris, France — Where Marie and Pierre Curie lived and worked, discovering radium and exploring the mysteries of radiation.

Note: Many other countries of Europe had productive centers of science during the nineteenth century (and still have in the twentieth century). A few of the most prominent are mentioned by name on the map. Today the scientific revolution is worldwide and many universities and private laboratories on all the continents are doing productive scientific work.

SPIRIT ...

Time and space are meaningless without spirit. Spirit is the part in each of us that understands. The part that sees connections between words and things–connections that surprise and make sense. Study the key words, concepts and ideas below so that you can understand how time, space and spirit worked in the past–and are working today.

Arabs — People from the Arabian peninsula who adopted the Moslem religion and spread their culture throughout the Middle East, southwestern Asia and northern Africa during the Middle Ages. Arab and Moslem scholars played an important part in preserving and adding to the scientific and mathematical achievements of the earlier Greek philosopher/scientists. (p. 4)

astrology — A pseudoscience that claims to understand the past and to predict the future based upon the positions of stars, planets, etc. (p. 14-15)

astronomy — The science of stars, planets, etc. (p. 5-6, 15)

capitalism — A form of economic organization in which private property, free markets and individual freedom are valued. Its rise was important in providing social base for scientific and industrial revolutions of the seventeenth to nineteenth centuries in Europe and North America. (p. 7)

Curie, Marie — French scientist of early twentieth century who won two Nobel Prizes for her work in discovering radioactive elements and unravelling some of the mysteries of radiation. (p. 10)

Dalton, John — English schoolteacher who built first modern atomic theory in early nineteenth century. (p. 8)

Darwin, Charles — English naturalist who proposed most widely accepted theory of evolution by natural selection in the mid nineteenth century. (p. 9)

democracy	A form of political organization that values individuality, constitutional rights and equality of opportunity. Along with capitalism, important in providing a base for scientific and industrial revolutions of nineteenth century in Europe and North America. (p. 7, 19-20)
Edison, Thomas	American inventor and technology genius. Nineteenth and early twentieth century. Given credit for inventing the electric light bulb, phonograph, motion picture, and other electrical devices, as well as inventing new methods of industrial research organization. (p. 11, 16)
hypothesis	An educated guess. A proposition you try to prove true or false by experiment. Often considered essential to scientific methods. (p. 16)
Galileo	Often considered the father of modern physics (and science). Lived and worked in Italy during the Renaissance and discovered important laws of motion. (p. 5, 9)
Industrial Revolution	The very great changes in human life styles that were brought about by modern science and technology in the nineteenth century. Began in England but quickly spread throughout Europe and North America, and is now rapidly spreading throughout the world. (p. 7)
Middle Ages	The thousand-year time in Europe between the fall of the Roman Empire to the beginning of the Renaissance around 1400. (p. 4-5)
Moslems	Followers of the religion of Mohammed, a prophet who lived in the seventh century A.D. Moslem scholars preserved and added to the scientific and mathematical discoveries of ancient Greek culture. (p. 4)
Newton, Isaac	Often considered the greatest scientist who ever lived. In seventeenth century England, Newton discovered the laws of motion and of gravity, and invented calculus. (p. 6)

occult	Refers to magical, pseudoscientific studies with ancient roots but few, if any, practical achievements. (p. 15)
Renaissance	The time between 1400 and 1700 in Europe when great changes took place as the ancient Greek and Roman cultures were rediscovered and modern science and art began to blossom. (p. 5-6)
scientific method	Read this book.
technology	The use of skill and knowledge to invent, produce and operate useful machines, and devices for the benefit of human life. (p. 1-2)
verification	Testing whether a hypothesis is true or false. (p. 12, 14, 16, 19)

In addition to the above, SCIENTIFIC METHODS & VALUES also teaches about other important people, places, things and ideas. Often you can figure out the meaning of a new term by seeing how it is used in context. Make sure you know the meaning of the following (for help, check the pages listed in this Learning Power Book, as well as your dictionary and encyclopedia):

Aristotle (p. 4); **Babbage, Charles** (p. 9); **Cambridge University** (p. 25); **Cavendish, Henry** (p. 9); **Crick & Watson** (p. 23); **DNA** (p. 23); **Democritus** (p. 3); **epidemic** (p. 7, 23); **Ford, Henry** (p. 23); **Hippocrates** (p. 4); **horoscope** (p. 14); **Lovelace, Ada** (p.9); **Nobel Prize** (p. 10); **paradox** (p. 19); **philosopher** (p. 3); **Roman Empire** (p. 4); **Sophocles** (p. 1, 21); **Thales** (p. 3); **Whitman, Walt** (p. 11).

STUDY SUGGESTIONS ...

1. In a short program, much detail must be left out. Investigate and report on the history and the differences in methods and values of individual sciences such as astronomy, physics, chemistry, biology, geology and psychology. Why did the most mathematical and far-out of the sciences, astronomy, develop earliest, and one of the most observational and close-to-home of the sciences, biology, take so long to mature?

2. Investigate and discuss why the social sciences lag far behind the physical and life sciences. Are the social sciences scientific? Pay special attention to differences in methods and values.

3. Derek de Solla Price, contemporary historian of science, claims that we have grossly underestimated the part played by technicians in the development of science. See bibliography for references to his work. Read and discuss in class, relating what he says to what you see today in the modern industrial and scientific world in your own community.

4. The ancient Greek philosopher Democritus is generally given credit for having been the first to propose an "atomic theory." Compare and contrast his theory with that of John Dalton some 2400 years later.

5. To better appreciate the differences and likenesses among scientists, read biographies of famous scientists of the past and compare and contrast with each other. The Isaac Asimov reference in the bibliography has hundreds of good thumbnail biographies to choose from.

6. Many people today believe in astrology or other occult practices. This book emphasizes the diversity of methods that could still be called scientific. Investigate and discuss why astrology or other occult "sciences" are considered unscientific by virtually all scientifically literate people.

7. Judge Learned Hand's statement, "The spirit of liberty is the spirit that is not quite sure it is right," is one of the best guides to the importance of scientific methods and values today. Sadly, some scientists are as guilty as anyone of violating this law. Especially when they go outside their specialty and promote political causes in issues like nuclear power, ecological balance, population growth, natural resources, toxic wastes, etc. Analyze the statements and arguments of prominent scientists today as they appear in the newspaper, on television and in popular magazines in the light of this "law" of Judge Hand.

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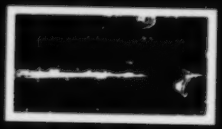

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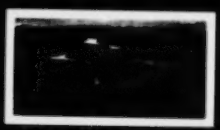

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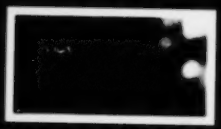

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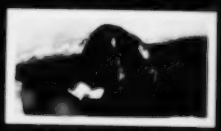

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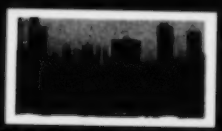

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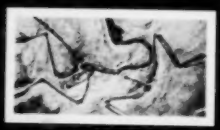

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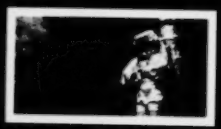

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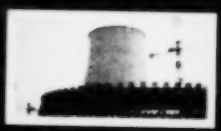

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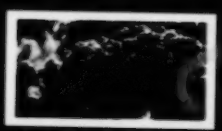

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